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Electric Field, Electric Field due to point charge, Electric field lines

CLASS-XII

SUBJECT : PHYSICS
CHAPTER NUMBER: 01
CHAPTER NAME : ELECTRIC CHARGES AND FIELDS

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LEARNING OUTCOME

After this lesson, students will be able:

- To understand that all sources of charge create an influence or action upon other objects some distance away and that the electric field concept is used to describe that influence.
- To state the mathematical definition of the electric field (force/charge) and to describe the dependence of the electric field strength upon the variables that affect it.
- To use an understanding of the convention for electric field direction to identify the electric field direction around a source charge.
- To construct and to interpret electric field line diagrams for isolated charges and collections of two or more charges.
- To use the electric field equation, Coulomb's law equation, and Newton's laws to analze physical situations that involve electric fields and to solve physics word problems associated with such situations.

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Slide 2

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-Swoyan Satyendu
, 17-06-2020

REVIEW

1. State Superposition principle?
2. What is a linear charge?
3. What is the surface charge?
4. What is the volume charge?
5. What are continuous charge distributions?

Electric Field

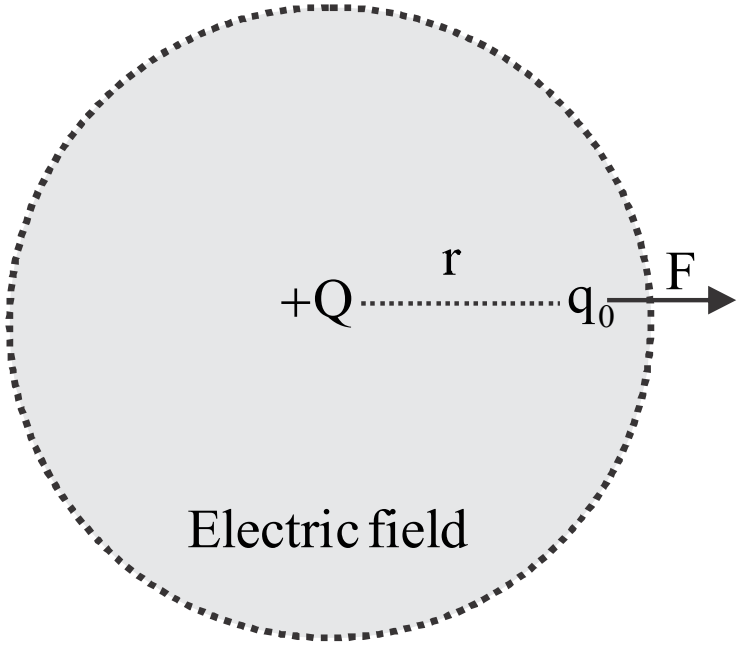
Something (invisible) existing in the space around every charge in which its effect is realized is called electric field.

Electric Field

Electric Field Intensity

Quantitatively it is defined as the force, a unit positive charge would experience if it is placed at that point without disturbing the position of source charge.

Mathematically, $\vec{E} = \frac{\vec{F}}{q_0}$



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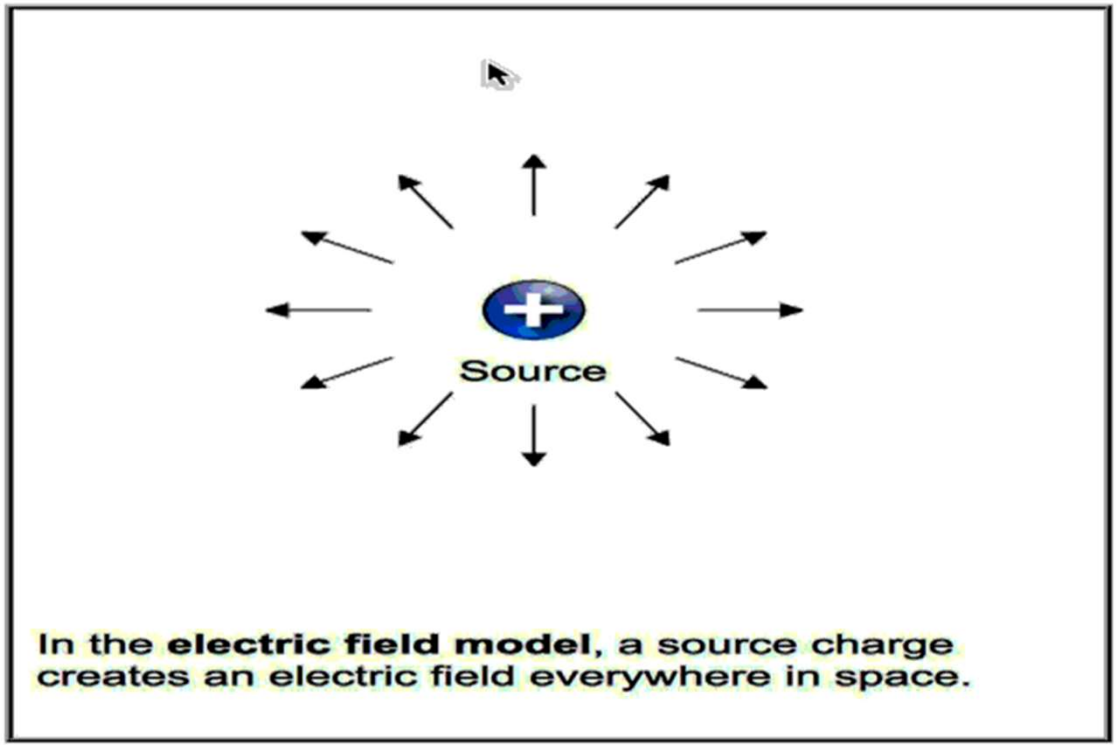
Electric field due to an Isolated Charge

Let ‘P’ be a point at a distance ‘r’ from the source charge ‘Q’.

$$\vec{E} = \frac{1}{4\pi\varepsilon_0}\frac{Q\vec{r}}{r^3}$$



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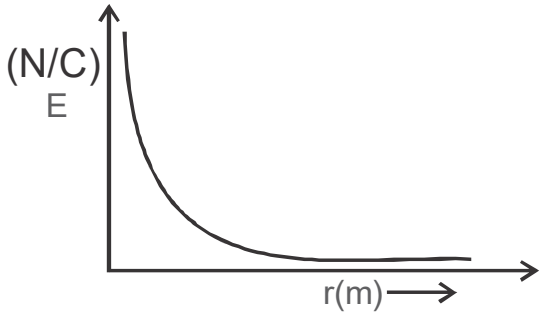
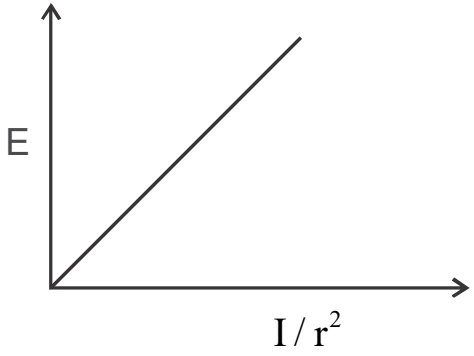
Graphical Representation

(variation of electric field with distance from the source)

Variation of E with r



Variation of E with $\frac{1}{r^2}$



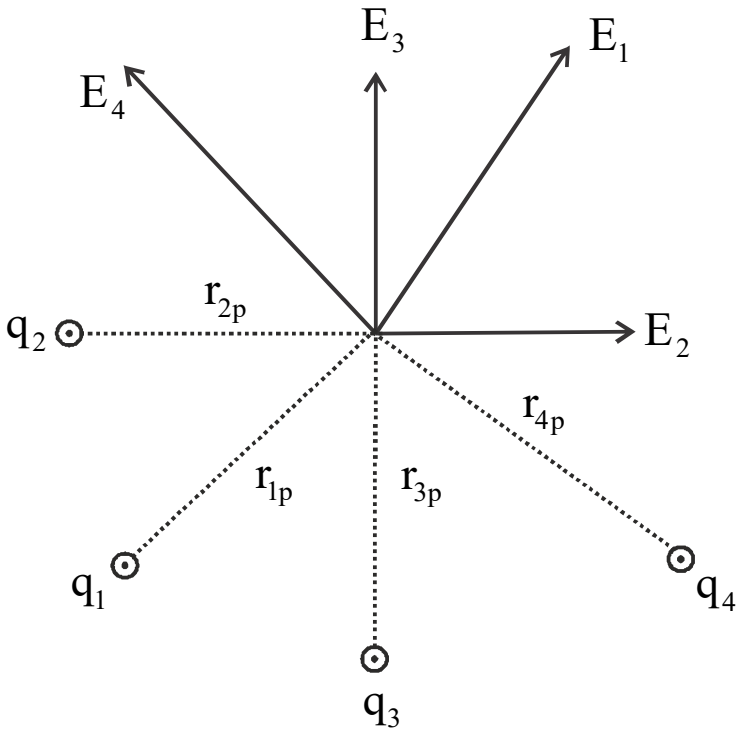
Electric field due to multiple charges

$$\vec{E}_1 = K\frac{q_1}{r_{1p}^2}\hat{r}_{1p}$$

$$\vec{E}_2 = K\frac{q_2}{r_{2p}^2}\hat{r}_{2p}$$

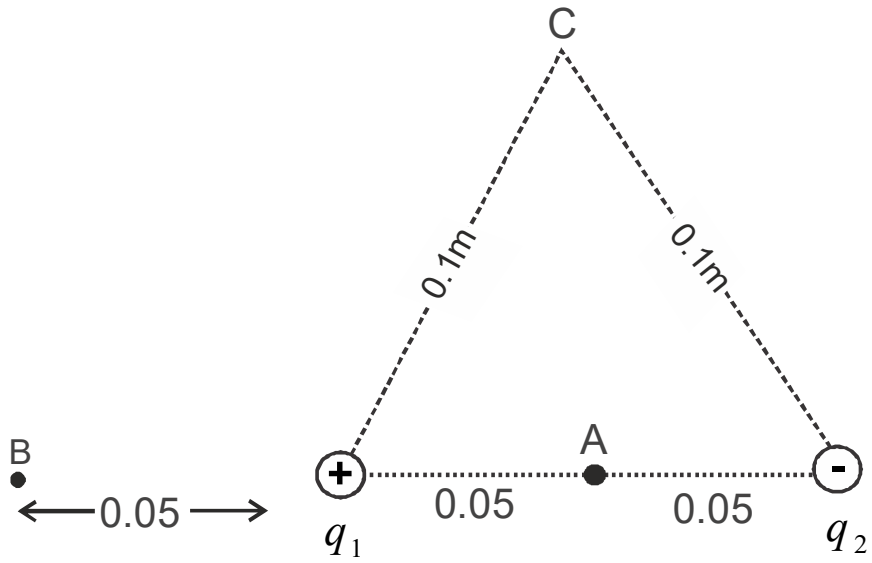
$$\vec{E}_n = K\frac{q_n}{r_{np}^2}\hat{r}_{np}$$

$$\Rightarrow \vec{E}_{net} = K\left[\frac{q_1}{r_{1p}^2}\hat{r}_{1p} + \frac{q_2}{r_{2p}^2}\hat{r}_{2p} + \ldots\ldots + \frac{q_n}{r_{np}^2}\hat{r}_{np}\right]$$



Numerical

Question: Two point charges q_1 and q_2 of magnitude $+10^{-8}$ C and -10^{8} C respectively are placed 0.1 m apart. Calculate the electric field at point A, B and C shown in the fig.



Question: If a charge is displaced from its position, then after what time, the field at a distance r will change?

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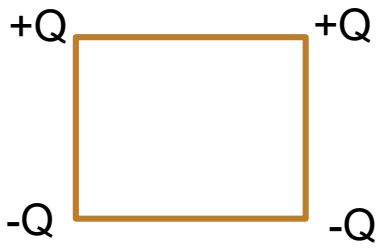
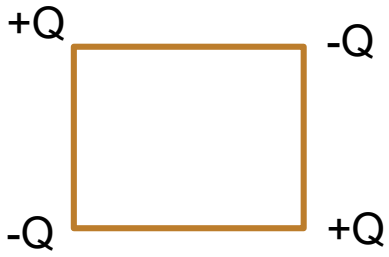
Numerical

Four point charges are placed at the four corners of a square in the two ways as shown in the fig. will the electric field at the centre of the square , be the same or different in the two configuration and why?





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Motion of a Charged Particle in an Electric Field

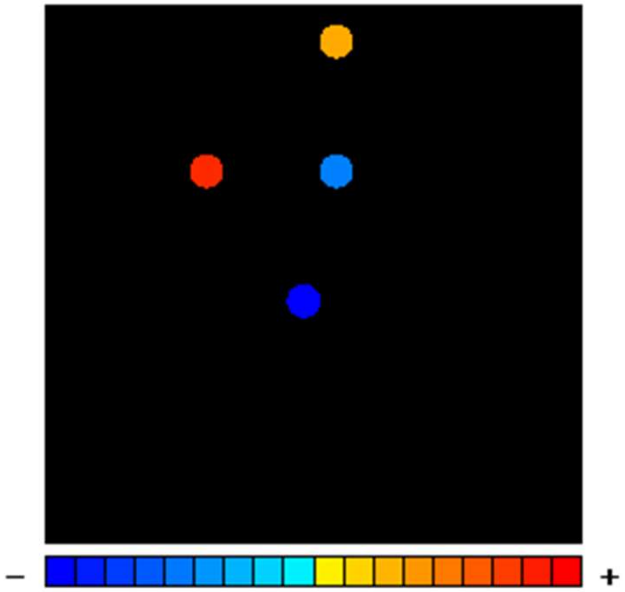
Acceleration of charge in uniform field is given by $\vec{a} = \frac{\vec{F}}{m} = \frac{q\vec{E}}{m}$ = constant.

So equation of motion is valid. Now there are two possibilities.

(a) If the particle is initially at rest

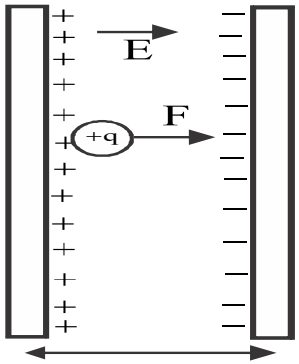
(b) If the particle is projected perpendicular to the field with an initial velocity V_0

Movement of a Charged Particle Under an Electric Field

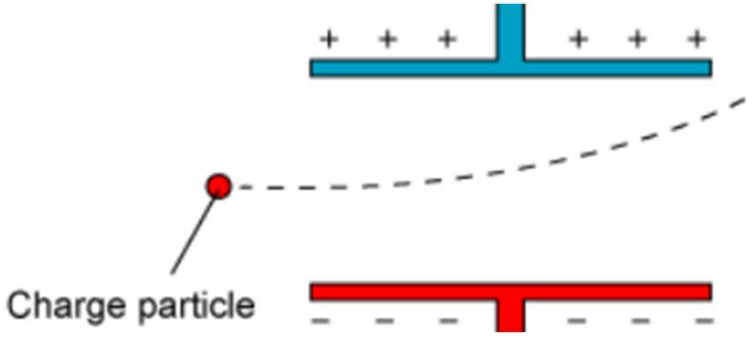


Motion of a Charged Particle in an Electric Field

(a) If the particle is initially at rest



(b) If the particle is projected perpendicular to the field with an initial velocity v_0



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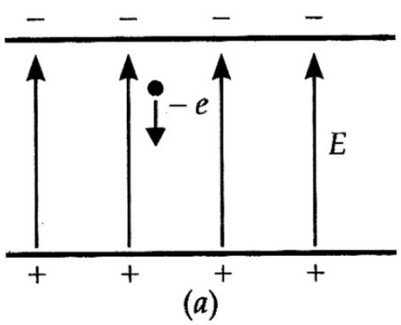
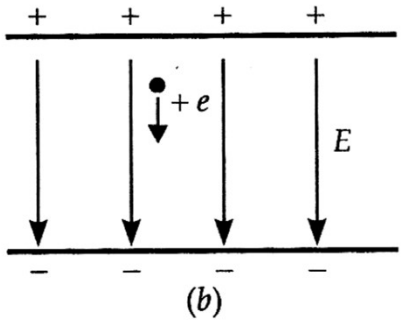
Numerical

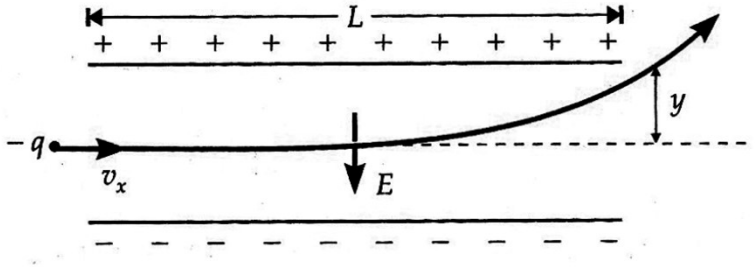
Question: An electron falls through a distance of 1.5 cm in a uniform electric field of magnitude $2.0 \times 10^4 NC^{-1}$. The direction of the field is reversed keeping its magnitude unchanged and a proton falls through the same distance. Compute the time of fall in each case. Contrast the situation

(a) with that of free fall under gravity. (NCERT)

(b) If the particle is projected perpendicular to the field with an initial velocity V_0.







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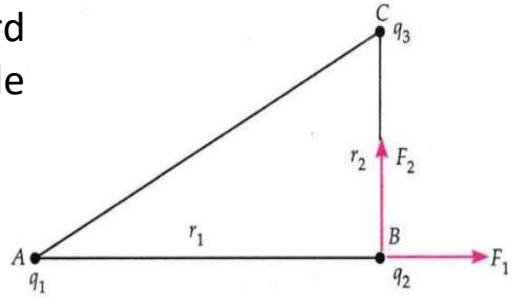
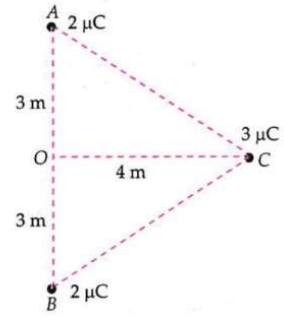
Home Assignment

1. Ten positively charged particles are kept fixed on the x-axis at points x = 10 cm, 20 cm, 30 cm, ..., 100 cm. The first particle has a charge 1.0×10^{-8} C, the second 8×10^{-8} C, third 27×10^{-8} C, and so on. The tenth particle has a charge 1000×10^{-8} C. Find the magnitude of the electric force acting on a 1 C charge placed at the origin. (Ans. 4.95×10^5N)

2. Charges q_1 =1.5 mC, q_2 = 0.2 mC and q_3 = - 0.5 mC are placed at the points A, B and C respectively, as shown in Fig. If r_1 = 1.2 m and r_2 = 0.6 m, calculate the magnitude of resultant force on q_2. (Ans. 3.125×10^3 N)



3. Two equal positive charges, each of 2 µC interact with a third positive charge of 3µC situated as shown in Fig. Find the magnitude and direction of the force experienced by the charge of 3 µC. (Ans. 3.456×10^{-3} N, along OC produced)



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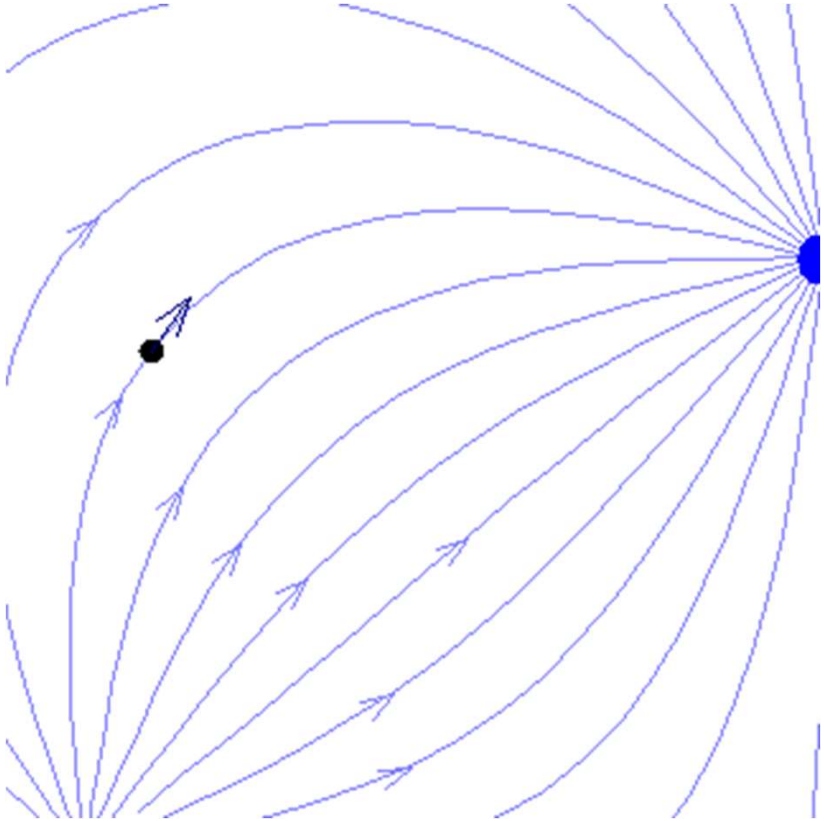
Electric Field Lines

An electric field can be visualized graphically in terms of electric field lines.

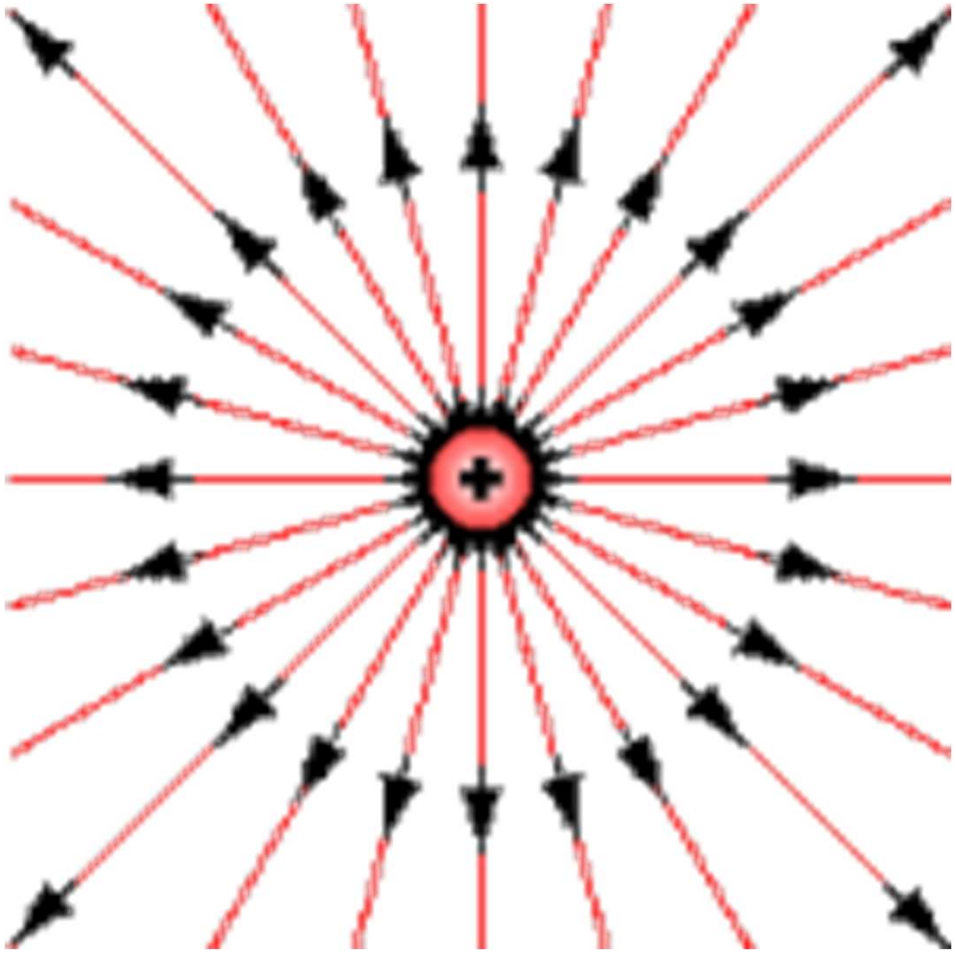
Definition

Electric field lines are defined as the paths along which a unit +ve charge moves, if it is free to do so.



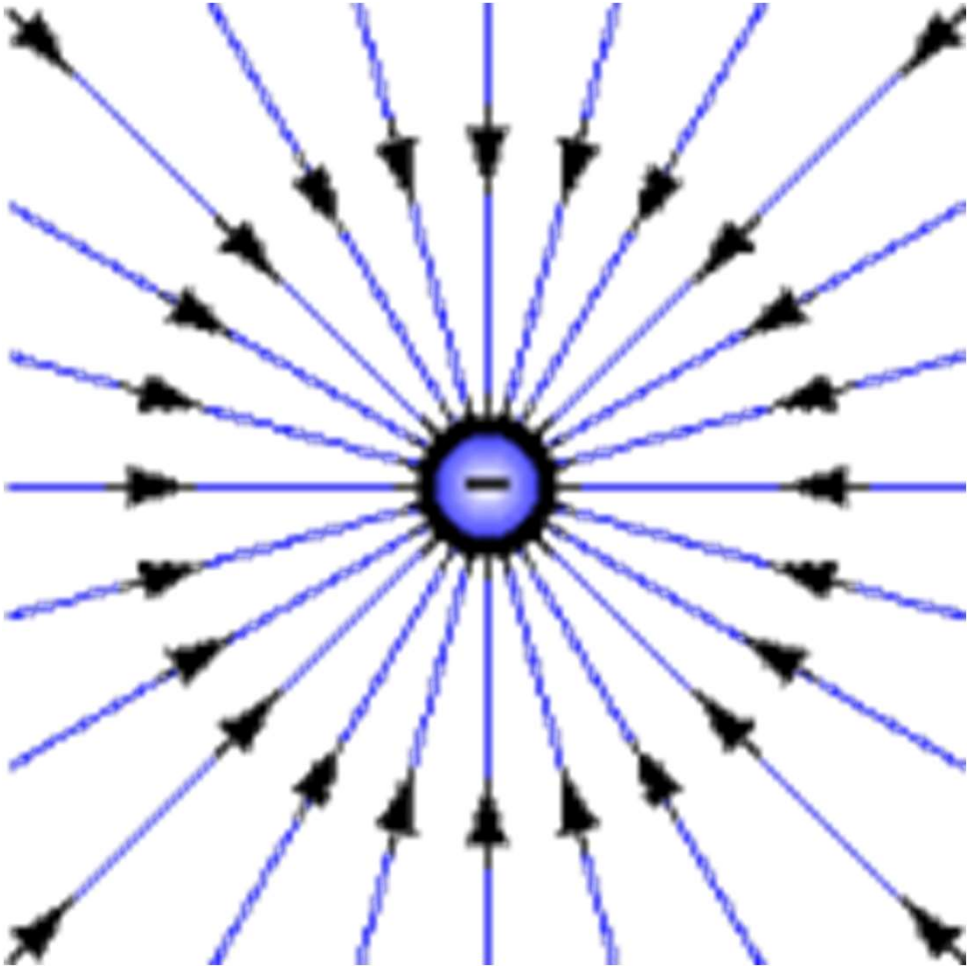
Electric Field lines due to some Charge Configuration

Field lines due to positive charge



Electric Field lines due to some Charge Configuration

Field lines due to negative charge



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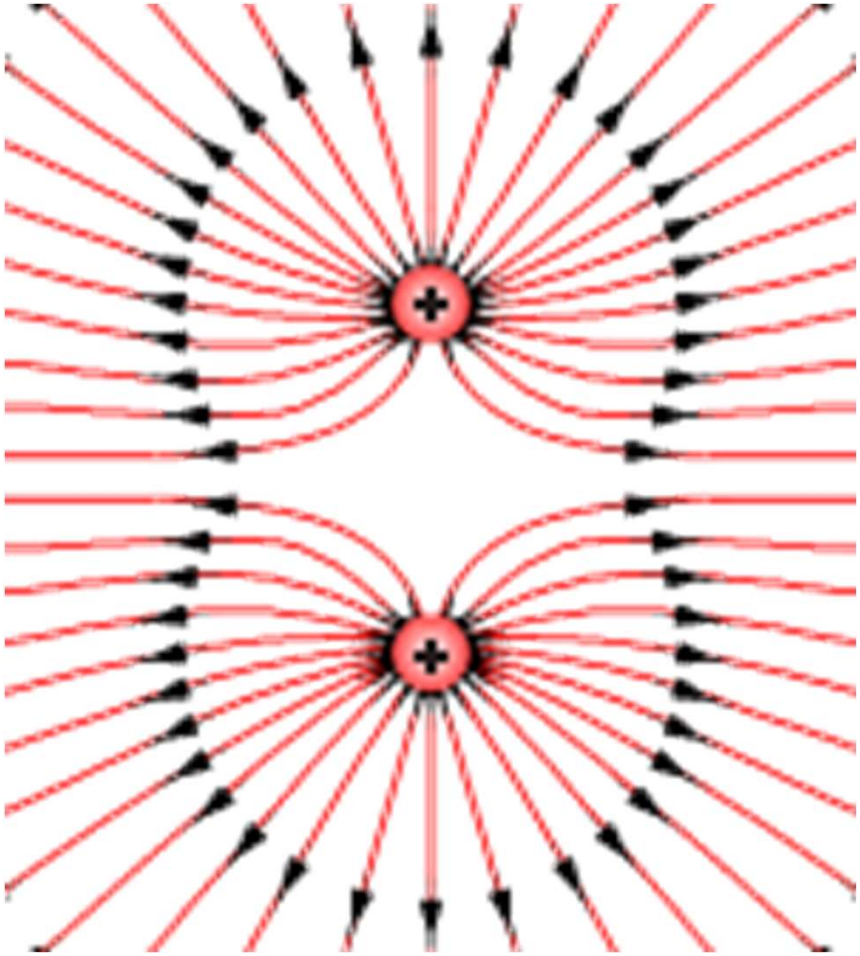
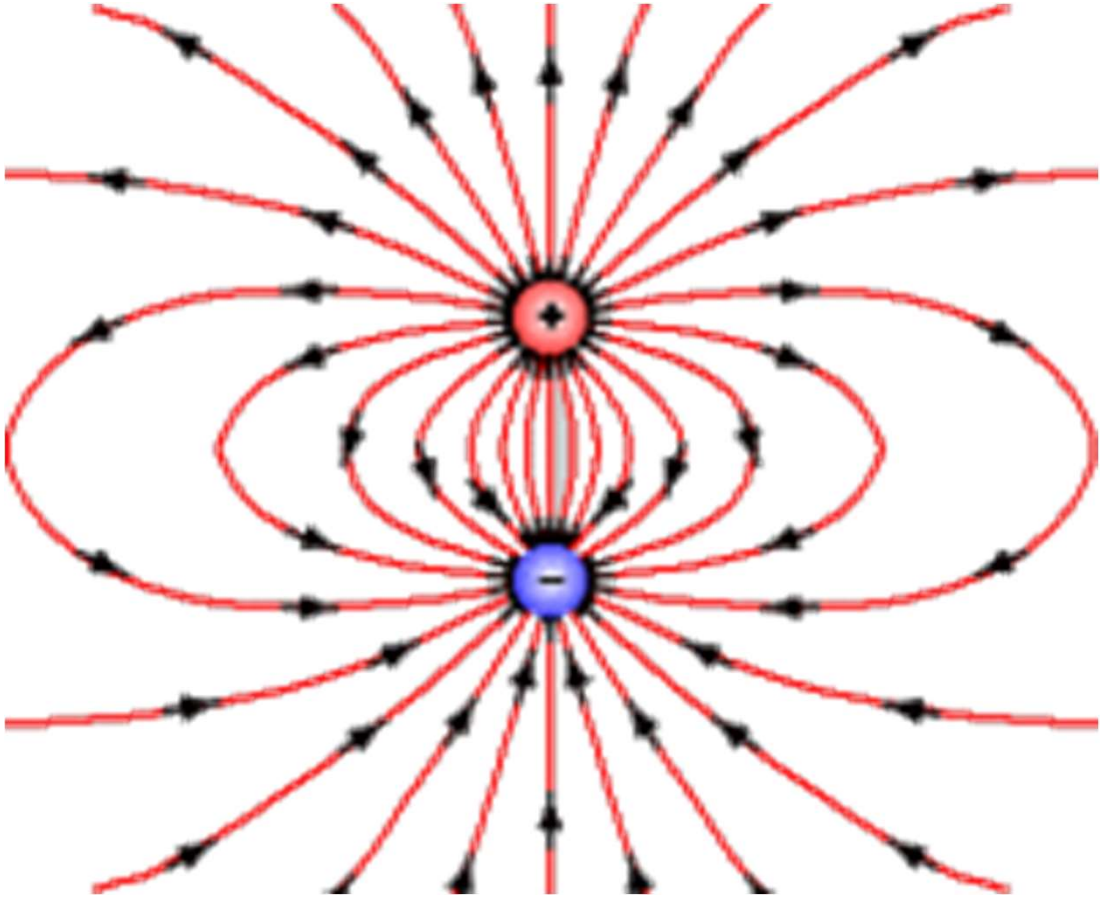
Electric Field lines due to some Charge Configuration

Field lines due to two positive charges



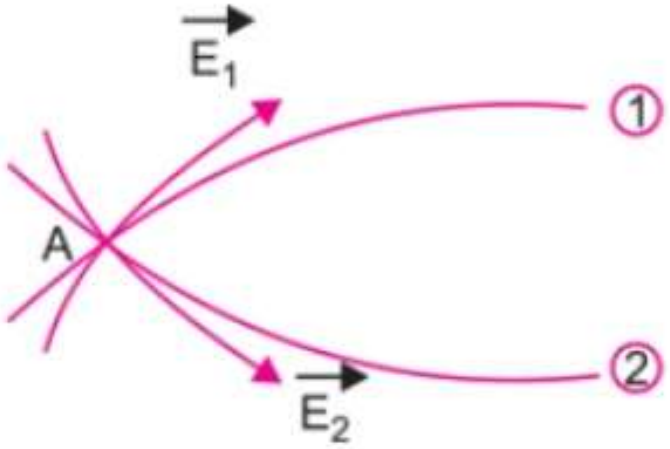
Electric Field lines due to some Charge Configuration

Field lines due to a dipole



Properties of Electric Field lines

- Field lines originates from +ve charge and terminates at –ve charge. But for isolated charge they may start or end at infinity.
- In a charge free region, field lines can be taken to be continuous curve without any break
- Field lines never cross each other. (Reason - At the point of intersection, two tangents can be drawn which shows two direction at a single point which is impossible)



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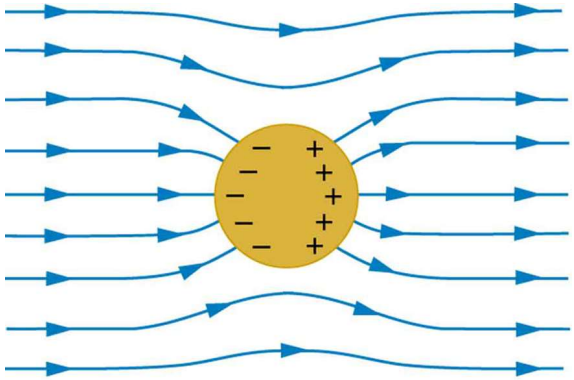
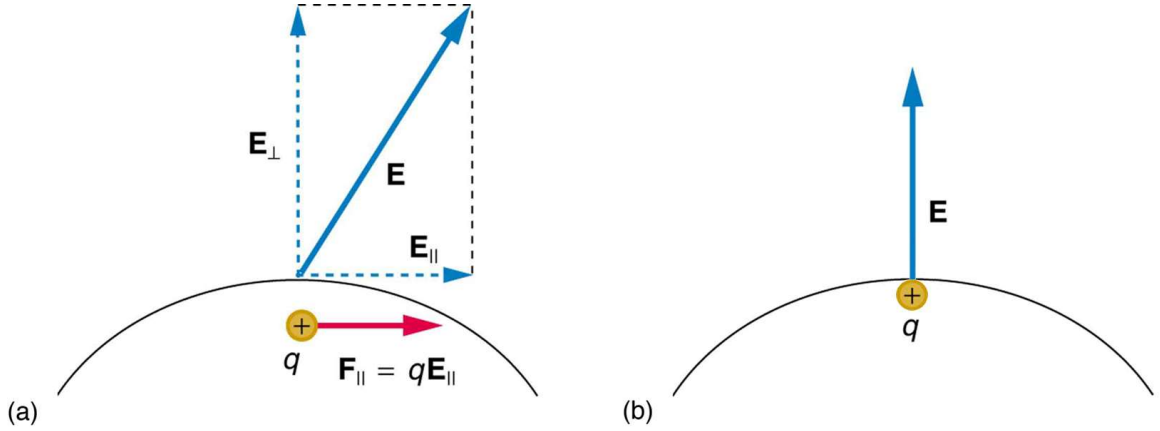
Properties of Electric Field lines

- Field lines do not form any close loops. i.e field lines never pass through conductor that justify the absence of electric field within the conductor.

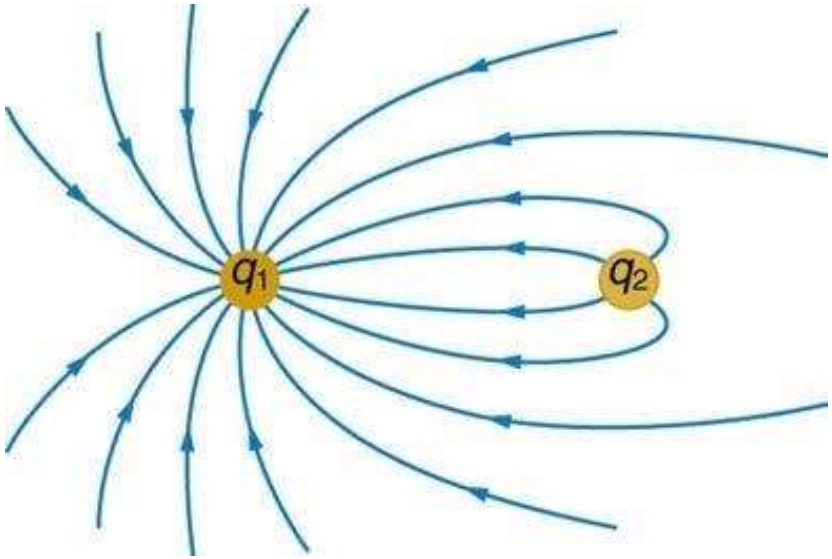


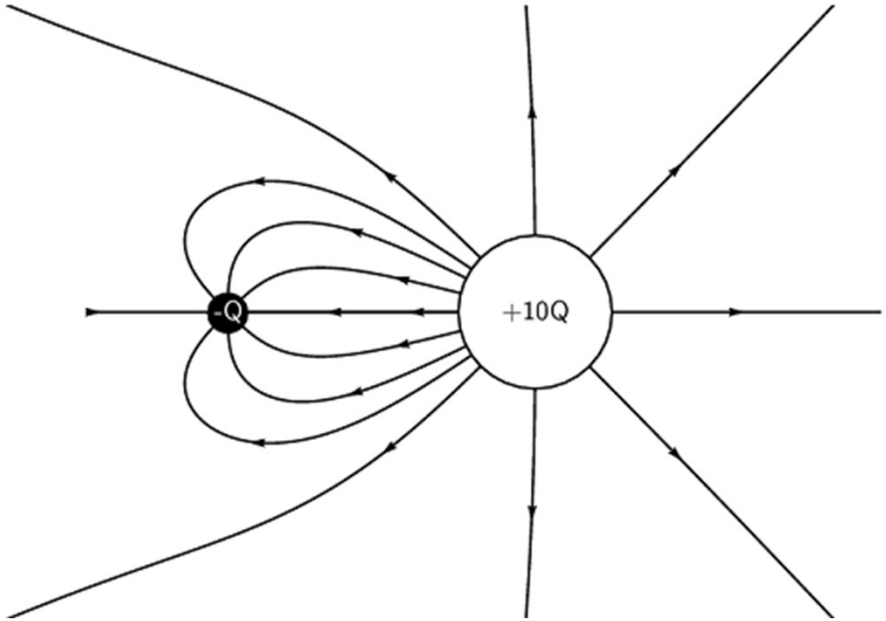
- Field lines are always normal to the surface of conductor in electrostatic condition.



Properties of Electric Field lines

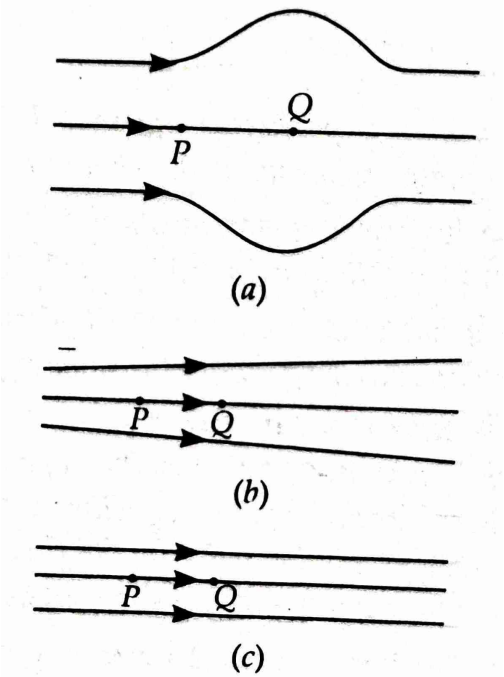
Relative closeness of field lines gives a measure of strength of the field.



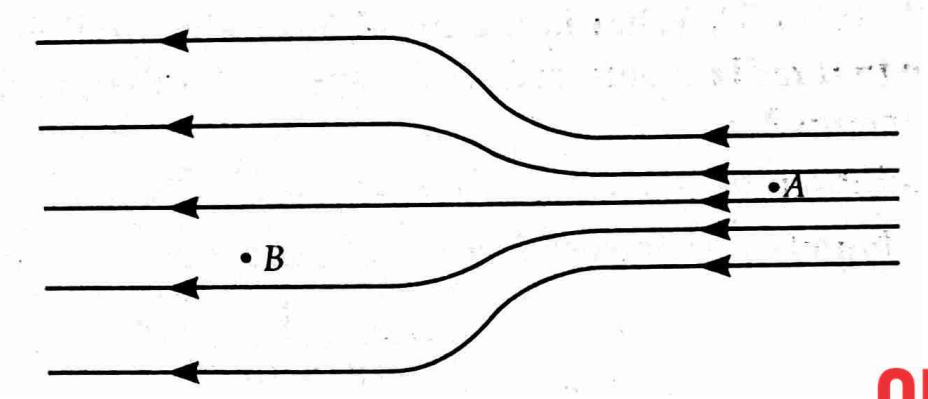


NUMERICAL

1. Figure shows three different patterns of electric field lines. In each pattern , a proton is released from rest at point P and then accelerated towards the point Q by the electric field. Rank the patterns according to the linear momentum of the proton when it reaches Q , greatest first.



2. In the electric field shown in the figure , the electric field lines on the left have twice the separation as that between those on the right. If the magnitude of the field at point A is 40N/C, calculate the force experienced by a proton placed at point A . Also find the magnitude of electric field at point B.



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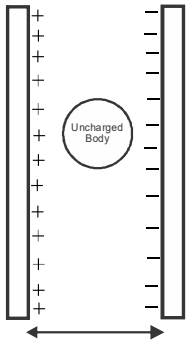
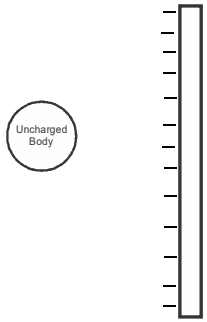
Numerical

Draw the electric field lines for the following charge configuration

a) Between $+q_1$ and $-q_2$ such that $|q_1| = 2q_2$

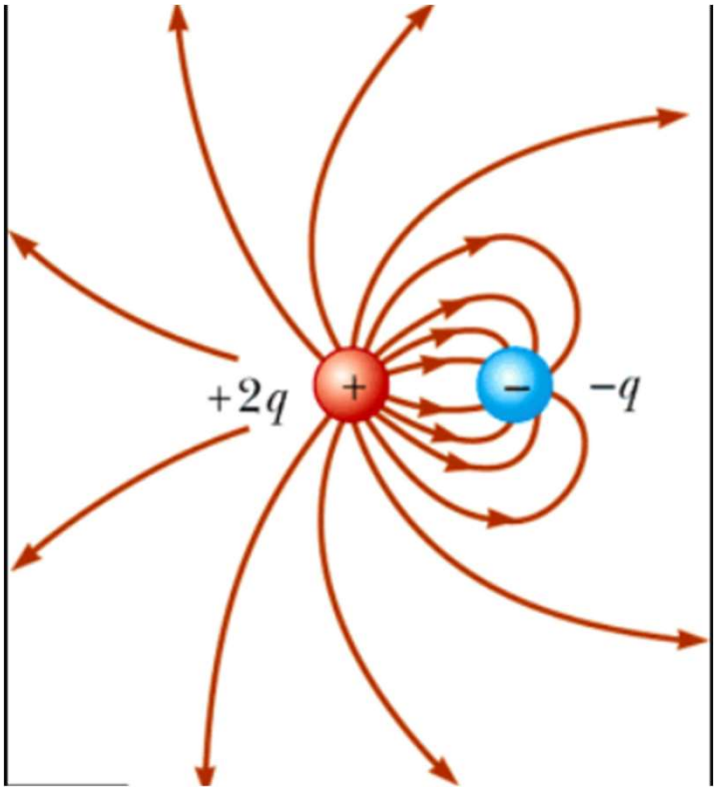
b) Between two parallel equal and oppositely charged plates.

c) 

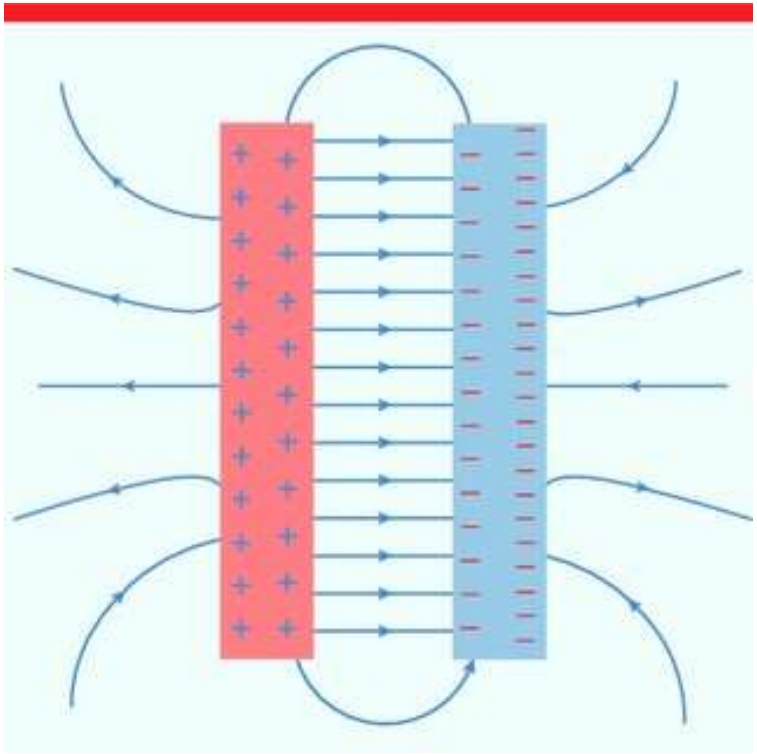
d) 

e) For some non uniform electric field.

Numerical



(a)



(b)

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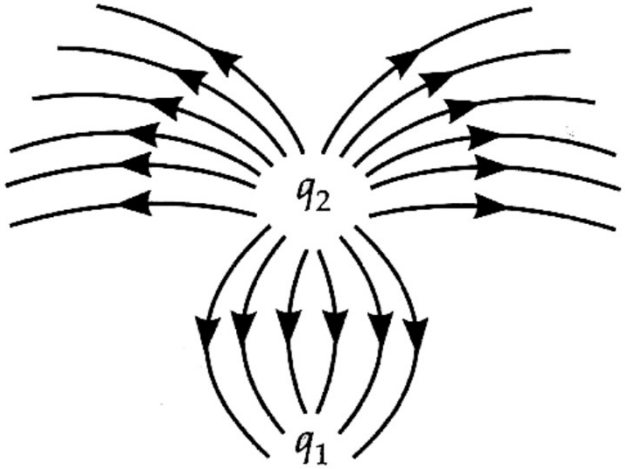
In the given figure what are the signs of q_1 and q_2?

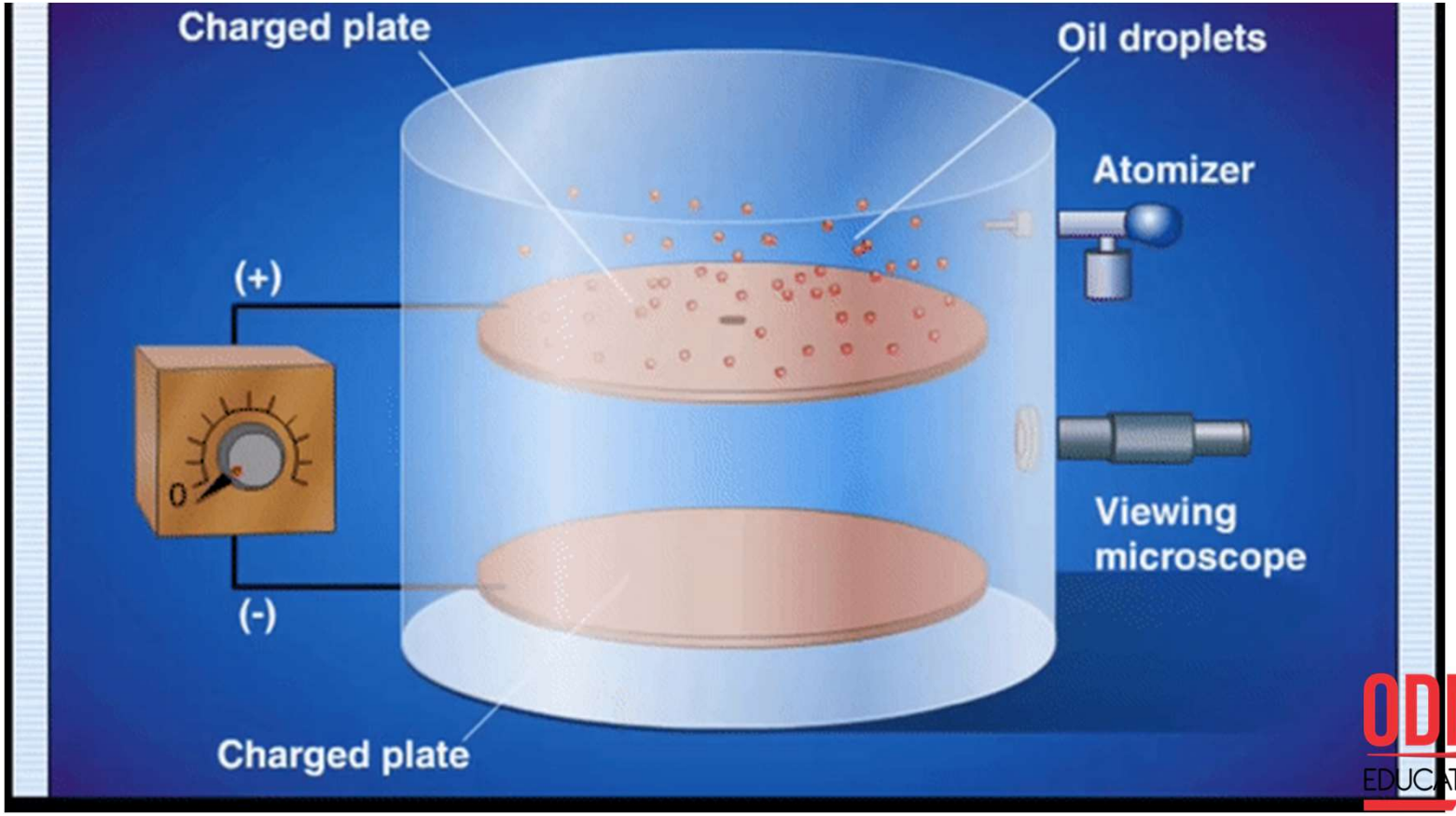
Also find the ratio of q_1/q_2



Millikan's Oil drop Expt. (Quantitative approach)

Determination of charge:

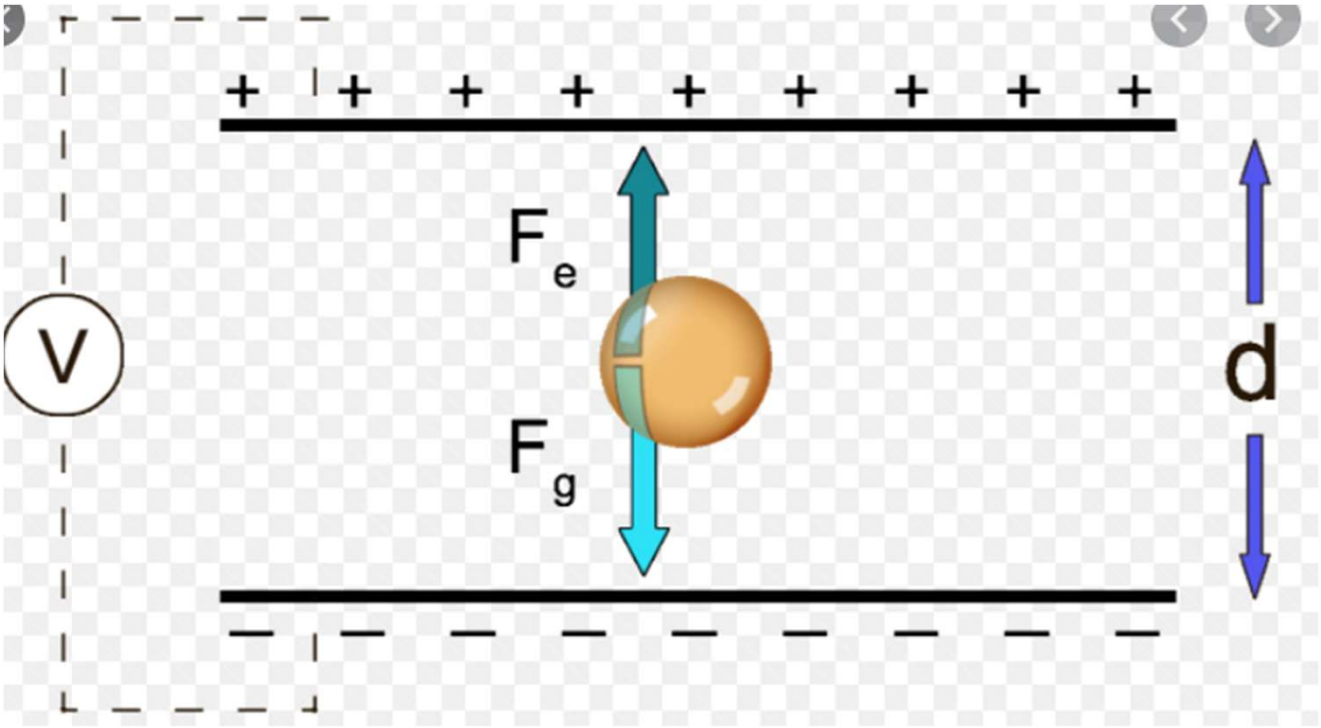
Electric field between the plates are adjusted in such a way that the drop remain at rest.



Radius of the Drop

Case – 1 : Drop is not allowed to fall

$$r = \left\{\frac{3neE}{4\pi\rho g}\right\}^{1/3}$$



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Question: An oil drop of 12 excess electrons is held stationary under a constant electric field of $2.55 \times 10^4 Vm^{-1}$ in Millikan's oil drop experiment. The density of the oil is $1.26\ g\ cm^{-3}$. Estimate the radius of the drop. ($g\ =\ 9.81\ m^{-2}$). (NCERT)

SOLUTION

$$r = \left\{\frac{3neE}{4\pi\rho g}\right\}^{1/3}$$

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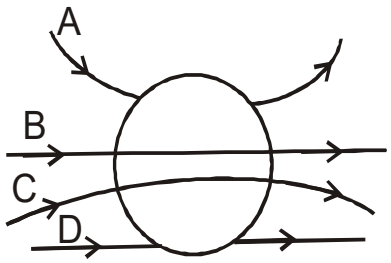
HOME ASSIGNMENT

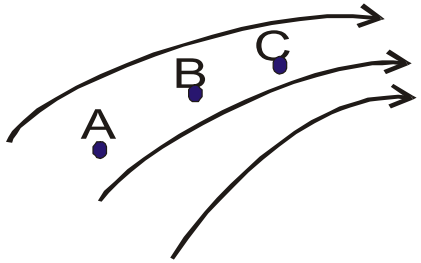
1. Force experienced by an electron in an electric field ‘E’ is F Newton. What will be the force experienced by the proton in the same field?

2. Which lines of force are correct?



3. An electric field is represented as shown in the figure.

Arrange the electric field in decreasing order.



4. Point charge (+Q) is kept in the vicinity of an uncharged conducting plate. Sketch electric field lines between the charge and the plate.

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THANKING YOU

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